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During the period of the AASERT the graduate student completed experiments and a Ph. D. dissertation on microwave emission of large and small orbit rectangular cross section (RCS) gyrotron devices. Rectangular interaction cavities with both small orbit and large orbit axis encircling electron beams were used in gyrotron mechanisms to generate hgit power microwaves.

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(AASERT)
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1. Grantee identification data: (R&T and Grant numbers found on Page 1 of Grant)

   a.   University of Michigan
      University Name

   b.   F49620-95-1-0329   c.   3484/TS
      Grant Number   R&T Number

   d.   Ronald M. Gilgenbach   e.   From: 1 June 95   To: 31 May 98
      P.I. Name   AASERT Reporting Period

NOTE: Grant to which AASERT award is attached is referred to hereafter as "Parent Agreement".

2. Total funding of the Parent Agreement and the number of full-time equivalent graduate students (FTEGS) supported by the Parent Agreement during the 12-month period <u>prior to</u> the AASERT award date.

   a. Funding: $ 221,897

   b. Number FTEGS: 1

3. Total funding of the Parent Agreement and the number of FTEGS supported by the Parent Agreement during the current 12-month reporting period.

   a. Funding: $ 0   (ended June 14, 1995

   b. Number FTEGS   0

4. Total AASERT funding and the number of FTEGS and undergraduate students (UGS) supported by AASERT funds during the current 12-month reporting period.

   a. Funding: $ 113,510

   b. Number FTEGS: 1

   c. Number UGS: 0

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VERIFICATION STATEMENT: I hereby verify that all students supported by the AASERT award are U.S. Citizens.

Ronald M. Gilgenbach   22 June 98
Ronald M. Gilgenbach   Date
Principal Investigator

During the period of the AASERT the graduate student completed experiments and a Ph. D. dissertation on microwave emission of large and small orbit rectangular cross section (RCS) gyrotron devices. Rectangular interaction cavities with both small orbit and large orbit axis encircling electron beams were used in gyrotron mechanisms to generate high power microwaves. The Michigan Electron Long Beam Accelerator (MELBA) produced an annular electron beam with e-beam parameters: V= -0.7 to -1.0 MV, I_{diode}=1-10kA, I_{tube}=0.1-3 kA, and e-beam pulse length=0.4-1.0 μs. The small orbit e-beam was spun up into an axis encircling e-beam by passing it through a magnetic cusp prior to entering the RCS interaction cavity. The issues under investigation included polarization control of the microwave emission as a function of the interaction cavity magnetic field, microwave power as a function of pulse length, and mode competition. Along with microwave power measurements, cold tests utilizing a network analyzer were conducted, and frequency analysis was conducted with the use of a heterodyne mixer. Measurements of the optical emission of plasma in the RCS interaction cavity beam dump have also been completed.

Experimental results in the small orbit gyrotron demonstrated powers up to 23 MW in the horizontal polarization with little power measured in the vertical fundamental mode, and hence, polarization control was not obtained. Pulse shortening was observed in the small orbit gyrotron and power efficiency was typically less than 1%. Radiation darkening on glass showed that adiabatic compression of the e-beam produced a beam α ($v_\perp / v_\parallel$) of approximately 0.3 for the small orbit gyrotron. EGUN simulations agreed with these results, showing the e-beam's α to be between 0.2 and 0.3, increasing witht eh magnitude of adiabatic compression.

The large orbit gyrotron, operating at a lower current, produced much more successful results. Powers as high as 14 MW were measured in the fundamental TE_{101} mode at a frequency of 2.18 GHz, and 11 MW in the horizontally polarized TE_{011} mode at 2.85 GHz. The results showed a high degree of polarization [$P(TE_{101})/P(TE_{011})$ = 1000 or as low as 1/30] as a function of cavity B-fields. The megawatt microwave output shifts from the fundamental TE_{101} mode to the TE_{011} mode as the B-field is raised from 1.5 to 1.9 kG. Efficiencies in the large orbit gyrotron were found to be as high as 8 %. Experimentally, the average e-beam α was approximately 1.0 at a magnetic field of 1.5 kG and rose to an average of approximately 1.3 for a B-field of 2 kG.

The highest power microwave pulses were on the order of 100 ns and demonstrated pulse shortening. Optical emission spectroscopy demonstrated the formation of hydrogen plasma in the cavity or output waveguide; these results imply that microwave pulse shortening could be related to this plasma produced by the e-beam dumping against the output waveguide walls.

To reduce mode competition, tapered cavities were introduced to replace the uniform RCS cavity. These experiments met with limited success. Cavity B, which was tapered in the vertical dimension to attempt suppression of the higher order, horizontally polarized TE_{01} mode, lowered the peak power in that mode to a peak value of 3 MW; furthermore, the mode frequency was shifted up from 2.85 GHz to above 3 GHz. This did not cause the power in the fundamental mode to increase, and tapering did not enhance the polarization ratio. Cavity C was tapered in the horizontal dimension to suppress the TE_{10} fundamental mode, and in this case the TE_{101} mode did not appear at 2.18 GHz. Either the TE_{01} mode dominated due to this taper, or the fundamental TE_{101} mode frequency shifted up to the frequency of the TE_{102} mode.

MAGIC code simulations (both 2D and 3D) predicted the ability to shift the linearly polarized output from the fundamental TE_{10} mode to the orthogonally polarized TE_{01} mode.